CASE REPORT

Effects of Improvisational Dance on Balance in Parkinson’s Disease: A Two-Phase fMRI Case Study

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ABSTRACT. Aims: This two-phase pilot examined the effects of group-delivered improvisational dance on balance in people with Parkinson’s disease. Subsequently, functional magnetic resonance imaging (fMRI) was examined in one individual for changes in whole-brain functional network connectivity. Methods: In Phase I, seven community-dwelling adults (mean age 67) with middle stage Parkinson’s disease completed a 7-week improvisation dance series. In Phase II, one participant from the pilot group underwent brain scanning following a 5-day trial of dance. Results: Group pretest-posttest balance comparisons from Phase I were significant on the Fullerton Advanced Balance Scale (p = 0.017). Posttest scans in Phase II exhibited significantly increased network connectivity between the basal ganglia and premotor cortices. Conclusions: Improvisational dance resulted in functional gains in balance for people with Parkinson’s disease and merits further exploration. For one participant, functional improvements appeared to correlate with emergence of higher order neural functioning.

KEYWORDS. Parkinson’s, dance, balance, fMRI, global efficiency

INTRODUCTION

Motor deficits common to people with idiopathic Parkinson’s disease (PPD) impair their ability to meet the demands of everyday tasks safely and effectively (Conradsson et al., 2012). To date, many balance problems related to PPD remain resistant to pharmacological and even surgical treatments (Olanow et al., 2009). Thus, many advocate moderate-to-intensive exercise to counter multisystem disability in Parkinson’s (Hirsch & Farley, 2009). Exercise reduces motor symptoms, improves...
drug efficacy, and is potentially neuroprotective (Goodwin et al., 2008; Xu et al., 2010). At the same time, programs must be feasible to overcome participation barriers faced by adults willing to commit to exercise (Ellis et al., 2013).

Dance is an expressive art form enjoying worldwide popularity among PPD as a safe and enjoyable exercise form. Over the last decade, researchers have reported statistical and long-term clinical significance in balance and walking speed through Tango (Hackney & Earhart, 2010), Classical Ballet (Houston & McGill, 2012), and Modern Dance (Batson, 2010). The psychophysical and social benefits of dance appear to exceed those of comparable exercise forms (Hackney & Earhart, 2009).

Dance challenges autonomous physical and emotional expression by stimulating many sensorimotor systems (visual, auditory, somato-sensory, and vestibular) through whole body movement in complex environments and tasks. PPD often discover new abilities during dance because they can easily follow the teachers’ demonstration (visual and verbal cueing) or can entrain to rhythmic music (auditory cueing). Such cues successfully regulate steady-state locomotor movements (Lohnes & Earhart, 2011). Dance also challenges cognitive faculties such as perceptual awareness, attention, decision-making, judgment, problem solving, and memory (Stevens & McKechnie, 2005).

Spontaneous balance perturbations commonly encountered in everyday experience require flexible and adaptive movement strategies (Kim et al., 2009). For people with PPD, building adaptability into remedial balance program is needed to promote the kind of problem solving required to successfully encounter balance challenges. Various styles of dance have been shown to have a positive impact on functional balance and gait (Hackney & Earhart, 2010; Marchant et al., 2010). Studies generally support teacher-led demonstrations with visual and auditory cueing or music (rhythmic) entrainment (Nieuwboer et al., 2007; Batson 2010). Theoretically, improvisational dance reinforces the concept that, despite the negative impact on movement in PPD, everyone is still capable of imagining and generating movement that leads to improved functional capability.

What remains uninvestigated is the relationship between dance movement and flexible decision-making demanded in everyday problem solving – that is, whether a specific type of dance can impact positively on the ability of PPD to generate adaptive balance strategies on their own in daily living. Another unknown is the capacity of PPD to generate adaptive strategies for complex balance activities on their own without depending on these dance-related cues. Lastly, scientists should also explore the potential important correlations between behavioral plasticity and neuroplasticity from the impact of this type of perceptuo-motor learning.

**PURPOSE**

The purpose of this two-phase pilot was: (Phase I) to examine the effects of an intensive trial of group-delivered dance improvisation on balance and mobility and, (Phase II) for one participant, to examine brain changes on functional magnetic resonance imaging (fMRI) in a subsequent neuroplasticity case study.
METHODS

Phase I

Phase I consisted of seven community-dwelling adults (mean age 67 years, Table 1), with middle stage Parkinson disease, (Hoehn & Yahr scores between 1.5 and 3). Participants completed an improvisational dance class that consisted of 3 classes per week, each lasting an hour, for a period of 7-weeks (21 total hours of dance). Participants were recruited from local area support groups and physicians. All eligible participants signed informed consent, demographic data and fall history were collected, and pretest balance and mobility measures were performed. The Institutional Review Board for both Universities involved approved this study.

Balance outcomes included pretest-posttest scores on the Fullerton Advanced Balance Scale (FAB) (Rose et al., 2006) and the Timed Up & Go, both baseline (TUG) and cognitive (cTUG) tests (Shumway-Cook et al., 2000). All balance and mobility outcome measures were administered by a licensed physical therapist.

The FAB consists of 10 performance-based items which involve various balance activities including standing with feet together, standing functional reach, turning 360°, tandem walking, walking with head turns, stepping up onto and over a 6-inch bench, standing on one leg, standing on a foam wedge with eyes closed, two-footed jump, and testing for reactive postural control. Scores range from 0 to 40 points possible using a 5 point ordinal scoring scale (0–4). While test-retest reliability has not been determined for the FAB in a population of Parkinson’s adults, it has excellent test-retest reliability ($r = 0.96$) and interrater reliability (ICC = 0.955 – 0.999) (Rose, et al., 2006) in community dwelling older adults and in breast cancer survivors who received chemotherapy (ICC = 0.98 for both) (Klein et al., 2011). The FAB also has strong concurrent validity with the Berg Balance Scale (BBS) ($r = 0.75$) (Rose et al., 2006). The TUG and the cTUG are tests of dynamic balance and movement efficiency. In each test, a person is timed while responding to the request to rise from a chair, walk 10 feet, turn around, and walk back to the chair and sit down. The cTUG adds the dual-task challenge of performing this sequence while counting backward by 7 from a random number less than 100. The TUG standard error of measure in adults with PPD is 1.75 s (Dal Bello-Haas et al., 2011) with a minimal detectable change of 4.85 s, and a cutoff score indicating risk of falls in adults with PPD of >7.95 s (Dibble & Lange, 2006). The TUG test-retest reliability

<table>
<thead>
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<th>Categorical variables</th>
<th>n (%)</th>
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<tbody>
<tr>
<td>Female</td>
<td>5 (71.43%)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>6 (83.33%)</td>
</tr>
<tr>
<td>Assistive device use</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Fallen in previous year</td>
<td>1 (83.33%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continuous variables</th>
<th>Avg./SD</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>67 (10.21)</td>
</tr>
<tr>
<td>Hoehn &amp; Yahr Score</td>
<td>2.5 = Mode</td>
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Participant demographics.
in PPD is adequate ($ICC = 0.85$) (Steffen & Seney, 2008), with excellent ICC ($r = 0.99$) (Morris et al., 2001) and excellent convergent validity with the BBS ($−0.78$) (Brusse et al., 2005). High-speed motion capture video recorded pre- and posttest coordination changes during performance of a functional movement sequence, as well as various points during the dance intervention, but were analyzed at a later time.

All classes were held in an accessible dance studio equipped with a wood floor, Ballet barre, and mirrors. The dance protocol emphasized individual- and group movement creation without teacher mimicking, music entrainment, or being visually cued by the studio mirror. Two dance instructors trained in the improvisational dance protocol were present throughout each class, one primarily for safety. The class consisted of three distinct contexts: seated in chairs, at the Ballet barre, and ambulating across the floor.

Exercises in each of these contexts required subjects to problem-solve, generating movement on their own. These exercises were facilitated primarily in response to verbal cues and minimal visual prompts provided by the lead dance instructor who danced alongside the participants, without leading them in prescriptive movements. These cues increased the demand on each individual participant to trust his or her own capabilities, as opposed to relying on rhythmic entrainment, and mimicking either the teacher or the collective movement of the group. While the nature of improvisational dance did not allow practice of a prescriptive set of activities, every class did include cues that emphasized movement through large ranges of motion, changes in base of support, and variability in speed of movement. One example of a verbal cue was “walk from one side of the room to other and pause three times whenever you wish.” Other prompts asked for greater exploration of quality movement, such as imaging and then modeling swimming underwater (while seated in a chair).

**Phase II**

At the termination of Phase I (seven weeks later), the group continued voluntarily in a once-a-week community offering. Three months after conclusion of the study, the participant with the highest functional gains in balance was invited to participate in Phase II, an fMRI case study. She consented to brain scanning and refrained from all exercise for two weeks prior to the scanning.

All imaging data were acquired on a Siemens SKYRA 3T MRI scanner using the following protocol: Whole-brain gradient echo echo-planar (EPI) was used to detect Blood-oxygen-level dependence fMRI signal changes during rest and with a reaction time task (button pushing) (Ogawa et al., 1990; Turner et al., 1998) with a gradient system 45 mT/m and 200 T/m/s for each axis. The echo planar imaging contained the following parameters: 120 volumes with 35 contiguous slices per volume; slice thickness 5.0 mm; in-plane resolution of 3.5 mm × 3.5 mm; TR/TE = 2,000/25 ms. Functional data were normalized to an EPI template, resliced to a 4 × 4 × 5 mm voxel size and not smoothed in an effort to avoid creating local spurious correlations (Fox et al., 2005; Hayasaka & Laurienti, 2010; van den Heuvel et al., 2008). A band-pass filter (0.0945–0.084 Hz) was applied and motion parameters, global signal, white matter signal, and CSF signal were regressed from the data to limit physiological noise.
Correlation matrices were generated so that each cell represented the Pearson correlation coefficient between the functional time series of each possible voxel pair. In other words, each node served as a seed and all associations between all voxel pairs were evaluated. These matrices were then made sparse by defining the relationship between the number of nodes ($N$) and the average degree ($K$, or the number of links at each node) to be the same across subjects. Previous research has shown that similarly sized networks with an $L$ value of 2.5 show high intersubject metric reliability and minimal network fragmentation where $L = \log(N)/\log(K)$ (Watts & Strogatz, 1998). Data shown here used a threshold of 2.5 for the network size. Modularity analyses (Girvan & Newman, 2002) were performed to evaluate the community structure of the functional brain networks using an algorithm called QCut to define community partitions (Ruan & Zhang, 2008). A community is a collection of network nodes that are more interconnected with each other than with the rest of the network. The organization of the basal ganglia community, which was determined by the degree of links with neighboring structures, was compared before and after the dance intervention.

Following completion of the fMRI for the case participant, the entire dance group gathered again for an intensive 1-week (5 consecutive days of 1-h classes) of improvisational dance intervention utilizing the same dance exercise protocol as in the pilot study. The fMRI protocol was repeated for the one participant immediately following the last dance session.

**RESULTS**

**Phase I**

For Phase I, the difference in balance scores using the Wilcoxon Signed Ranks Test were significant for the group on the FAB ($p = 0.017$), with an average total improvement of 5.29 points (Figure 1). Individual changes in FAB scores are displayed in Figure 2. Although posttest scores on paired samples t-testing were not significant for either the TUG or cTUG, there was a trend toward decreased timing and decreased group performance variability. The average decrease in time to complete the TUG test was 2.34 s, while the average decrease in cTUG was 2.87 s. While these averages fall approximately 1.5 s short of a minimal clinically important difference, they do illustrate improvement in mobility and decreased fall risk.

**Phase II**

For Phase II, the postintervention scan showed a change in the organization of the basal ganglia community. Data showed whole brain connectivity patterns with increased long-range connections (global efficiency) and network communities. The default-mode brain network (known to be critical at rest) showed increased long-range connectivity after the dance treatment. A significant finding identified stronger connections between the anterior and posterior aspects of this network. The basal ganglia were in an isolated neuronal community prior to training and became highly interconnected with the premotor cortex after the week-long intensive trial. Figure 3 illustrates pretest-posttest comparisons of the resting brain scan.
FIGURE 1. Fullerton advanced balance scale testing results from Phase I ($N = 7, p < 0.017$).

DISCUSSION

For this group of individuals with middle stage Parkinson disease, a novel approach to dance improvisation resulted in short-term functional gains in balance. For one participant, functional improvements appeared to correlate with emergence of higher order neural functioning. Positive neuroplastic changes on fMRI recordings

Fullerton Advanced Balance Scale

![Fullerton Advanced Balance Scale diagram]

**FIGURE 2.** Individual scores for changes in pretest and posttest FAB, with column 8 representing the average change in FAB score post intervention.
FIGURE 3. Brain maps showing the extent of the basal ganglia neighborhood pre- and post intervention. The figure shows two axial slices through the bilateral basal ganglia (blue arrows) and the premotor cortices (red arrows). The basal ganglia neighborhood (green area) was identified using modularity analyses.

reflected possible increased strength in brain connectivity, particularly between the basal ganglia and cortical motor centers. Before training the basal ganglia were a community isolated from other regional connections. After brief, intensive training, the basal ganglia network (i.e., the neighborhood of nodal connectivity) (Girvan & Newman, 2002) showed a greater shared network community with the motor cortex. This case finding may suggest a preferential increase in basal ganglia connectivity with the premotor region. Further, results are promising for the capacity of improvisational dance to improve connections between the basal ganglia and other motor centers that directly impact mobility and balance. While the mechanisms for these neuroplastic changes are unclear, previous researchers have theorized that dance forms such as tango have resulted in improved movement outcomes due to increased multisensory cueing, increased attention to walking, and more automatic movement patterns (Earhart, 2009). Short, intensive doses of tango, in particular, have resulted in improved balance, walking velocity, participation in activity, and more normalized swing to stance ratios during gait (Hackney & Earhart, 2009). The improvements in balance resulting from improvisational dance would be less likely a result of cueing and automaticity, since music and step repetition are not a part of the class, and more likely a result of increased cognitive attention to new, self-generated motor tasks.

The small sample size of dance participants, as well as the single case for fMRI analysis, limits the extrapolation of these results to a larger population of people with PPD. Recruitment of participants with middle stage PPD, who were open to this type of activity and who could attend class three days per week, presented a challenge and contributed to the small sample size in this study. While recruitment was difficult at first, currently as many as 20 adults with PPD attend the ongoing improvisational dance class on a weekly basis, largely due to word of mouth regarding the benefits of the class.

Larger studies with longer intervention periods are warranted to substantiate correlations between functional gains and neural network connectivity through
improvisational dance in adults with Parkinson disease. The 7-week period of dance class may not be the best dose of this intervention for clinically significant outcomes. Intensive, short duration tango classes (10 classes over 2 weeks) have shown improvements in balance, walking speed, and cadence (Hackney & Earhart, 2009), as well as 10-week sessions resulting in positive trends in TUG performance (Earhart, 2009). A year-long randomized controlled trial utilizing Argentine tango also resulted in improved quality of life measures and increased activity participation (Foster et al., 2013). A 12-week trial of 150 min of improvisational dance per week may be a good next step in the continued investigation of dance dosage.

Future studies should also explore collection of variables that impact balance, such as strength, cognition, and sensory integration, to better understand the improvements in balance seen in this pilot study. Lastly, fMRI scanning should ideally be performed on participants who have had no previous exposure to improvisational dance and on a larger sample size in order to determine neuroplastic changes in brain function that may result from this novel intervention.

DECLARATION OF INTEREST

The authors report no declarations of interest. The authors alone are responsible for the content and writing of this paper.

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